An Advanced Fracture Characterization and Well Path Navigation System for Effective Re-Development and Enhancement of Ultimate Recovery from the Complex Monterey Reservoir of South Ellwood Field, Offshore California

Quarterly Technical Progress Report

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Progress Report April 1, 2002- June 30, 2002

Disclaimer

Abstract

Venoco Inc, intends to re-develop the Monterey Formation, a Class III basin reservoir, at South Ellwood Field, Offshore Santa Barbara, California. Well productivity in this field varies significantly. Cumulative Monterey production for individual wells has ranged from 260 STB to 8,700,000 STB. Productivity is primarily affected by how well the well path connects with the local fracture system and the degree of aquifer support. Cumulative oil recovery to date is a small percentage of the original oil in place. To embark upon successful redevelopment and to optimize reservoir management, Venoco intends to investigate, map and characterize field fracture patterns and the reservoir conduit system. State of the art borehole imaging technologies including FMI, dipole sonic and cross-well seismic, interference tests and production logs will be employed to characterize fractures and micro faults. These data along with the existing database will be used for construction of a novel geologic model of the fracture network. Development of an innovative fracture network reservoir simulator is proposed to monitor and manage the aquifer's role in pressure maintenance and water production. The new fracture simulation model will be used for both planning optimal paths for new wells and improving ultimate recovery.

In the second phase of this project, the model will be used for the design of a pilot program for downhole water re-injection into the aquifer simultaneously with oil production. Downhole water separation units attached to electric submersible pumps will be used to minimize surface fluid handling thereby improving recoveries per well and field economics while maintaining aquifer support. In cooperation with the DOE, results of the field studies as well as the new models developed and the fracture database will be shared with other operators. Numerous fields producing from the Monterey and analogous fractured reservoirs both onshore and offshore will benefit from the methodologies developed in this project.

This report presents a summary of all technical work conducted during the eighth quarter of Budget Period I.

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Introduction

The Field Demonstration site for this Class III (basin clastic) Program Proposal is the South Ellwood Field located offshore California. The Monterey Formation is the main producing unit in the South Ellwood Field and consists of fractured chert, porcelanite, dolomite, and siliceous limestone interbedded with organic mudstone. This reservoir has an average thickness of 1,000 feet, and lies at subsea depths of approximately -3,500' to -5,000'.

Venoco and USC jointly submitted an application to conduct a DOE co-operative investigation of the Monterey formation at South Ellwood in June 2000. The DOE granted this application in July 2000.

Executive Summary

Venoco and USC prepared a proposal for a DOE sponsored joint investigation of the fractured Monterey formation. It was agreed that Venoco would construct the geologic model for the field and gather new reservoir data as appropriate. USC would then develop a simulation model that would be used to optimize future hydrocarbon recovery. Joint Venoco-USC teams were established to manage the flow of data and insure that Venoco and USC activities remained synchronized. A co-operative agreement was signed with the DOE on July 31, 2000.

This cooperative work between the research team at USC and the operational engineers and geoscientist at Venoco has generated new insight into the evaluation methods for the Monterey Formation and has resulted in the formulation of new approaches to describe reservoir dynamics and to simulate reservoir performance for forecasting purposes. The project has made several contributions to the tech transfer goal of the U.S. Department of Energy. The most prominent of these are; the development of an interactive database on the Monterey Formation, a conceptual model for the description of fracture-controlled Monterey Reservoirs, a pattern recognition method for analysis of well log data and methods for subsurface control of high water production. The first tangible results from this study were obtained this quarter. The first Holly well, 3242-7-2, drilled since 1986 was successfully completed in the massively fractured Lower Monterey.

Task I- Database

We incorporated a number of interactivity functions to the web site. Included within the site are diagnostic plots of individual well performance data, a Fetkovich type curve matching process, visualization of directional surveys and real time plots of well log data.

Task II- New Data

3242-7-2 was the first well drillled by Venoco on Holly platform. The well was sidetracked from 3242-7-1 at a depth of 3274 ft. and drilled eastward to tap reserves in the lower Monterey near the eastern limit of the lease. The hole was built up to an angle of between 67° and 72° from vertical except for an interval from about 7000'-7500' where angles as high as 75° where reached. The top of the Monterey was encountered at 5672' and zone 1 to just into zone 2 were penetrated before crossing an expected fault at 5810' (MD) and drilling back into Sisquoc Formation. The top

Monterey in the main fault block was encountered at 6274' (MD) and a fairly complete section of Monterey into Zone 3 was drilled down to 7000' where Monterey strata dipping steeply 85° to the north were encountered. By about 7300' (MD) the beds were dipping steeply, mostly to the south, until about 7500' where the dip of the strata gradually flattened out to around 20°-15° southerly dips. This steeply dipping interval was difficult to correlate as the well drilled through it along strike. Below this interval a fairly "normal" section from Monterey zone 3 (repeated) through 7 was encountered. Circulation was lost at a depth of 7600' and never regained. Therefore no cuttings were available for examination.

Modern logs including Schlumberger's Formation Micro-Image Toll and the Dipole Sonic Tool were run to better describe the fracture system. The Lower M5, M6 and M7 (8320-9022') were perforated selectively using the FMI log to pick the most heavily fractured zones. The perforations were acid washed with mud acid and a 3-1/2" gas lift completion run. The zone was being production tested at report date.

Task III- Basic Reservoir Studies

We finalized our computational process for estimation of aquifer influx and the model was presented in a paper at the Western Regional Meeting of SPE.

Lithology Indicator System

The results of our study on lithology indication plots for a number of wells including the wells tested with the new production logging system of Schlumberger were presented at the Western Regional Meeting of SPE in Anchorage, Alaska

Simulation Studies

During this quarter, major progress has been made in the following aspects:
Finalized construction of a dual porosity model in IMEX builder based on the geological information furnished by the Venoco geologists.

- Incorporated the latest production data (for the period 06/01/2000 – 01/01/2002) into the dual porosity model. Table 1 shows South Ellwood Monterey Formation Cumulative Production (as of 01/01/2002)

Cumulative Oil, SC	Cumulative Gas, SC	Cumulative Water, SC
BBL	MCF	BBL
52,282,500	41,768,800	48,077,000

Table 1: South Ellwood Monterey Formation Cumulative Production (as of 01/01/2002)

- Continued the task of fine-tuning different parameters in the simulation model to obtain a better understanding of rock - fluid data, component properties, initial conditions, and aquifer properties.
- Revisited the production field history file (FHF), incorporating the latest production data.
- Initiated construction of a new model, which could incorporate the effect of communication of flow units through aquifer on reservoir pressure support (Figure

1). Definition of the nature of flow units for the model would be basically done through associating an initial water saturation contour map together with an initial pressure contour map with each of the existing layers of formation.

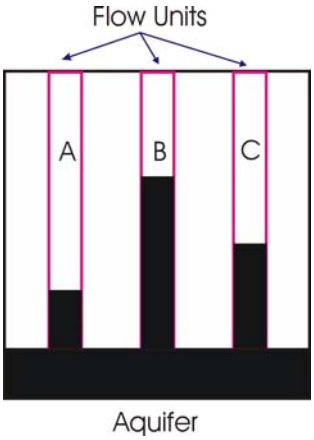

Figure 1: Possible mechanism for differential depletion and separate OWC.

- Initiated a comparative survey (simulation results vs. historical data), on the performance of individual wells to obtain a better understanding of the extent of aquifer support and influence of pre-defined local fractures on the producing conditions of each support. The results of the study would be used as a means of fine-tuning of the local parameters affecting production-related indicators of performance of each well within the model.
- Performed a detailed study of the results of preliminary well-by-well history matching runs. The results of the study confirmed the existence of isolated producing zones across the field and the necessity of revisiting historical performance data to identify the number and the relative location of these compartments.
- Performed a thorough study of production performance indicators across the field to find the groups of wells producing from the same compartment.
- Constructed a new dual porosity model in IMEX builder based on the number of isolated compartments identified. Figures 2 and 3 show 2-D and 3-D representation of preliminary compartmentalized reservoir model.
- Initiated preliminary history matching simulation runs for compartmentalized reservoir model. Figures 4 through 9 show comparative field-wide performance images of preliminary simulation runs versus actual.

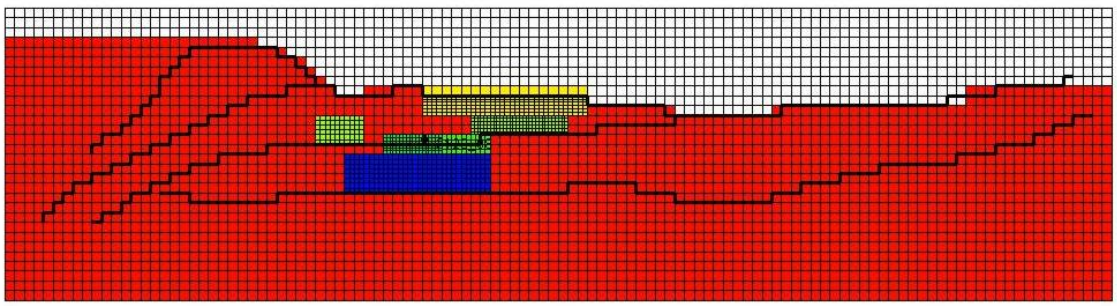

Figure 2: 2-D presentation of compartmentalized reservoir model

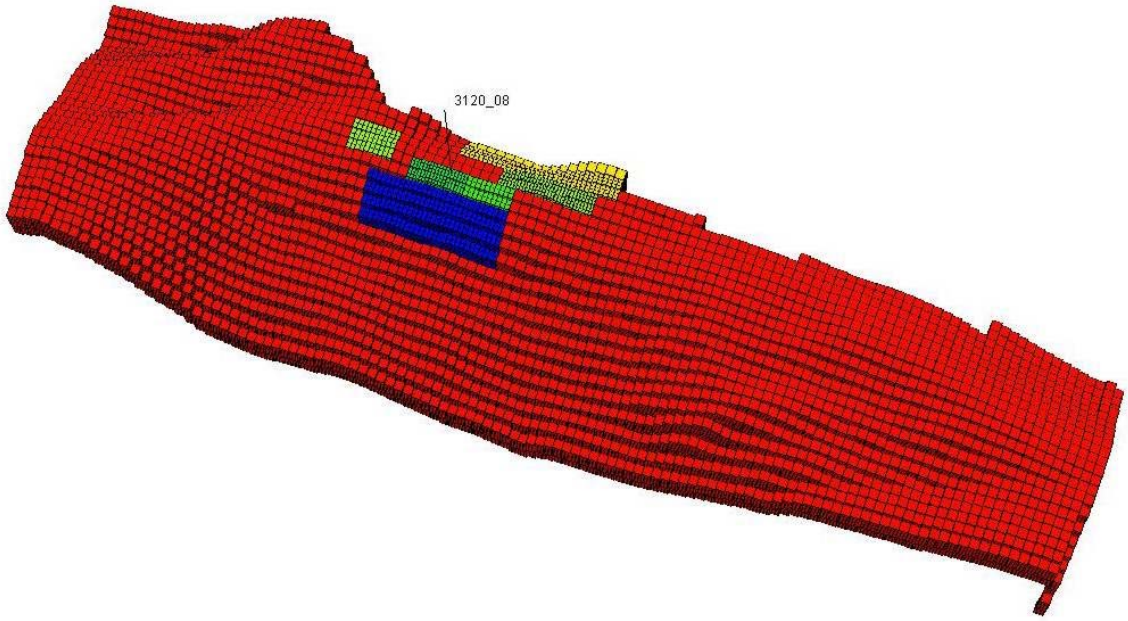

Figure 3: 3-D presentation of compartmentalized reservoir model

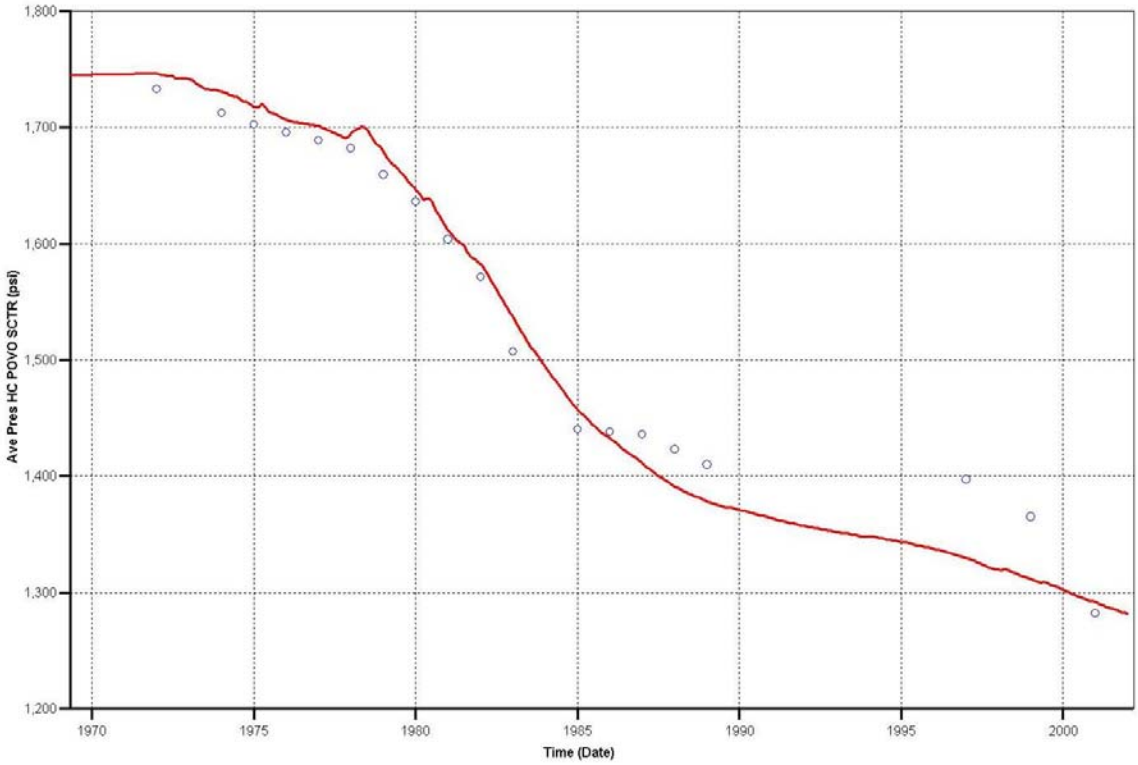

Figure 4: Pressure-simulation (solid line) vs actual (compartmentalized reservoir model)

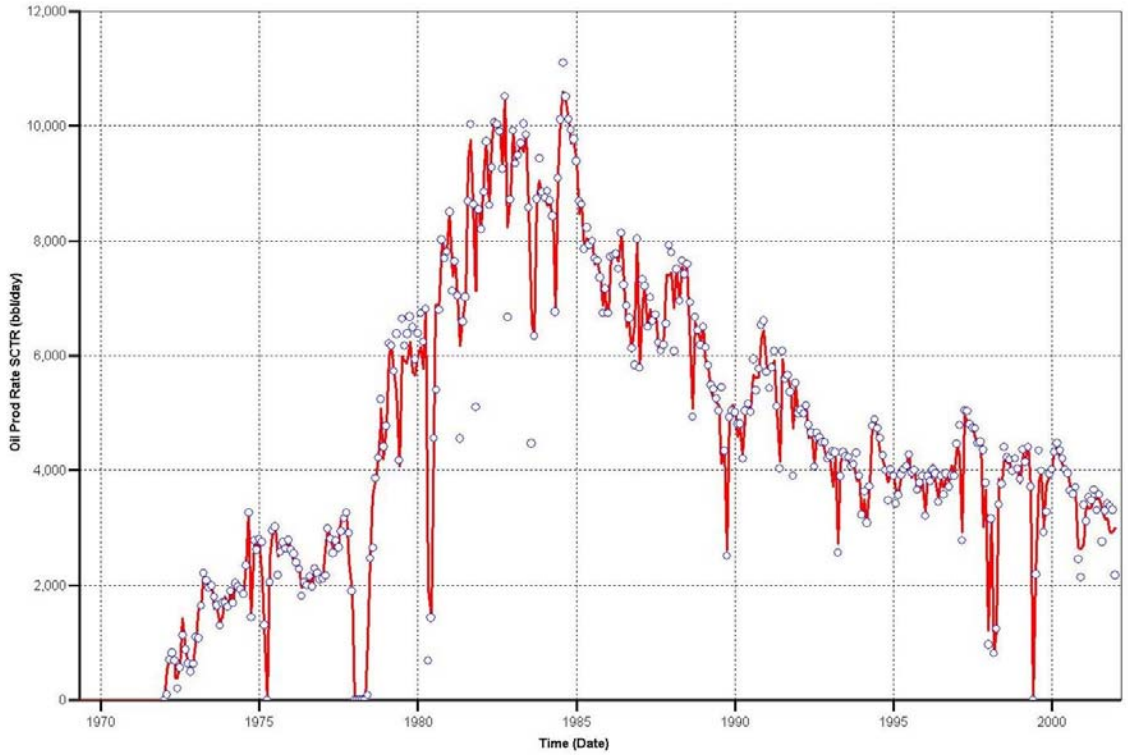

Figure 5: Oil rate-simulation (solid line) vs actual (compartmentalized reservoir model)

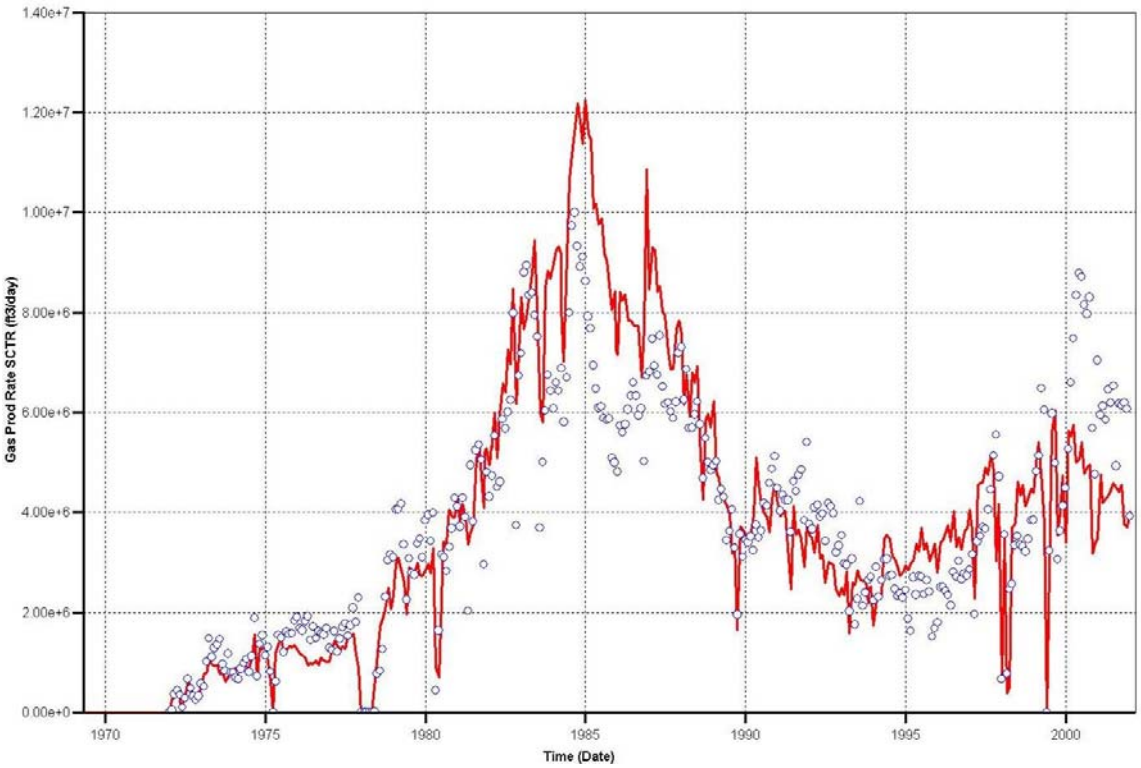

Figure 6: Gas rate-simulation (solid line) vs actual (compartmentalized reservoir model)

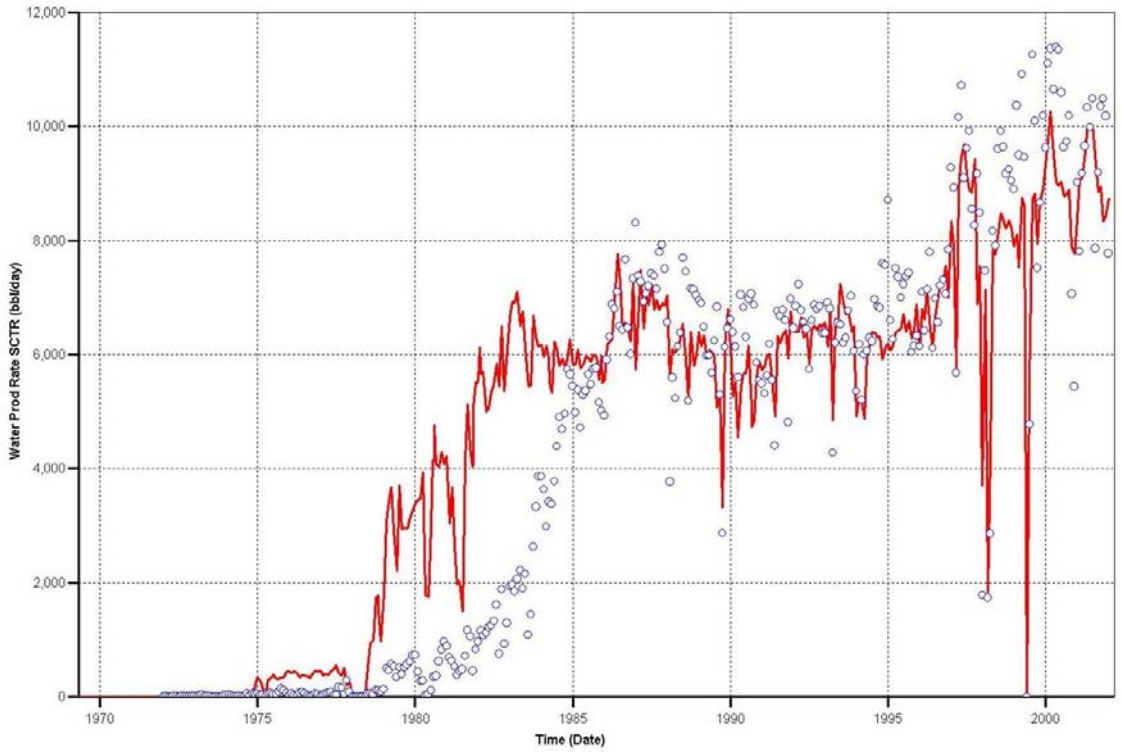

Figure 7: Water rate-simulation (solid line) vs actual (compartmentalized reservoir model)

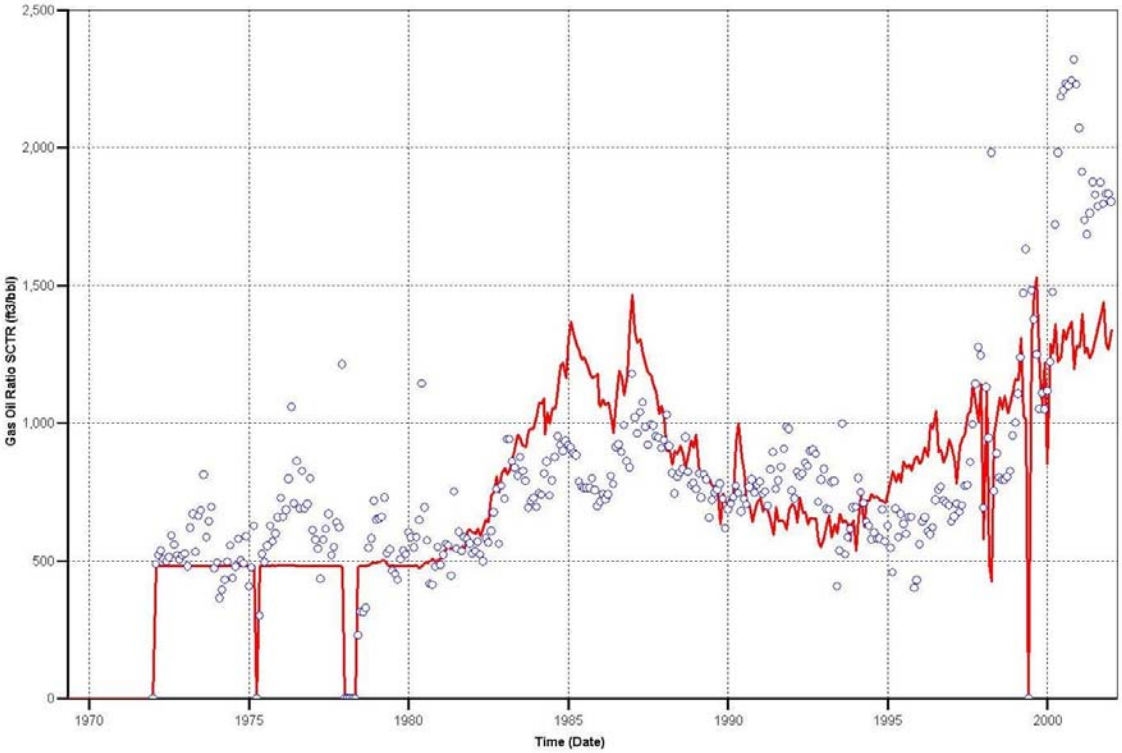

Figure 8: Gas Oil Ratio (GOR)-simulation (solid line) vs actual (compartmentalized reservoir model)

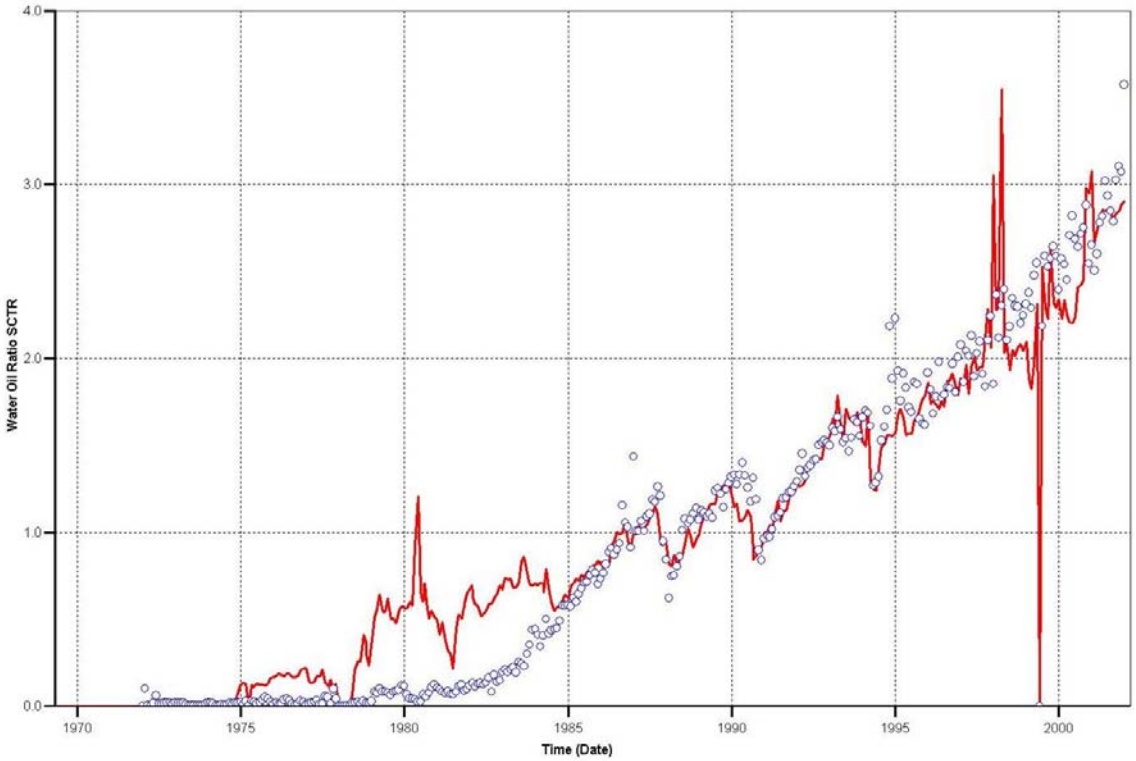

Figure 9: Water Oil Ratio (WOR)-simulation (solid line) vs actual (compartmentalized reservoir model)

- Developed a windows-based software package for calculation of cumulative water influx (based on Fetkovich approach) and associated deviations from the X-plot straight line.
- Developed the preliminary 2-D, 2P version of a windows-based black oil simulator based on pipe network model (PNM)

Work Schedule for the Next Quarter

The tentative work schedule for next quarter will be as follows:

1. Refining (compartmentalized reservoir model) grid configuration to gain a better control over local gridding effects on well-by-well history matching process.
2. Continuing fine-tuning of local parameters affecting production-related indicators of performance of each well within the model.
3. Performing preliminary well-by-well history matching simulation runs (compartmentalized reservoir-dual porosity model).

Task IV--Stimulation

The newly perforated zones of 3242-7-2 were acid washed with a conventional mud acid solution.

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Task V- Project Management

Project review meetings were held on a monthly basis in Carpinteria. Progress reports from various individuals were reviewed. Individuals working on the project during this quarter included:

Database:
I. Ershaghi (USC), H. Patel (USC), Tim Rathmann (Venoco), Katie Boerger (USC), Kim Halbert (Venoco) and Chris Knight (Venoco).

Reservoir Studies:
I. Ershaghi (USC), Doddy Abdassah (USC), A. Zahedi (USC), Zhengming Yang (USC),), Antho ny Taglieri (USC), Steve Horner (Venoco), M. Heidari (USC), M. Kashfi (USC), Raymond Ohusuafr (USC).

Geological Modeling
Mike Wracher (Venoco), Karen Christensen (Venoco), Marc Kamerling (Venoco)

Geophysical Modeling
Karen Christensen (Venoco)

Project Management:
Steve Horner (Venoco) and I. Ershaghi (USC)

Task VI-Technology Transfer

We presented three papers related to the project at the Western Regional Meeting of SPE in Anchorage Alaska, May 18-23, 2002.

SPE 76782
A Method for Detection of Untapped Intervals in a Complex Lithology Fractured System.
Anthony Taglieri, Doddy Abdassah, Iraj Ershaghi, University of Southern California and Kim Halbert, Venoco Inc.

SPE 76755
Characterization of Flow Channels, Natural Fractures Orientation and Oil Water Contact Movement From Well Productivity Data
Alireza Zahedi, SPE and Iraj Ershaghi, SPE, University of Southern California, and Steve Horner, Venoco, Inc

SPE 76781
Technology of Web Based Data Access for Reservoir Monitoring and Tech Transfer
Iraj Ershaghi, Ursula Wiley, Katie Boerger, Harshad Patil, University of Southern California, Steve Horner, Tim Rathmann and Kim Halbert, Venoco

We were also invited to present a talk at the Univ of Oklahoma's Conference on Naturally Fractured Reservoirs in Oklahoma City, OK on Monday, June 3, 2002

Reservoir Characteristics of Fractured Reservoirs of the Monterey Formation, **Iraj Ershaghi, U. of Southern California, Steve Horner and Karen Christensen, Venoco, Inc.**

Conclusions:
During this quarter we drilled a new well with modern logs. Schlumberger's Formation Micro-Image Tool gave clear evidence of an extensive fracture system with a pronounced North-South orientation. This log was used to pick perforations. The well is still being production tested to optimize the completion.

We made substantial progress in reservoir simulation work, and presented a number of papers at various conferences. We finalized the design and implementation of the web based data repository with inclusion of interactivity for various applications.